EDITORIAL

UNDERSTANDING AND CONCEPTUAL CHANGE IN SCIENCE AND MATHEMATICS: AN INTERNATIONAL AGENDA WITHIN A CONSTRUCTIVIST FRAMEWORK

This special issue of the *International Journal of Science and Mathematics Education* devoted to studies on learning celebrates the twenty-fifth anniversary of the constructivist reform effort in science and mathematics education (Ausubel, Novak & Hanesian, 1978; Driver & Easley, 1978). In recognition of this anniversary, more than thirty mission-based national projects on students' conceptions in science and mathematics were recently supported by the Division of Science Education of the National Science Council, Taiwan. The results of these studies have contributed a vast base of useful knowledge about student learning and teacher instruction.

One product of this effort was the recent *International Conference on Science and Mathematics Learning* (*ICSML*), organized for the purpose of discussing both theory and practice in science and mathematics learning and held in Taipei in December 2003. The Conference provided a forum for a wide range of topics and was designed to promote meaningful and research-based teaching activities. Several internationally recognized scholars from United States, United Kingdom, Australia, and Germany shared their insightful research experiences and thoughts in plenary addresses. Additionally, thirty two papers were presented addressing issues on conceptual structure, meaningful learning, and teaching strategies by researchers from Hong Kong, South Africa, and Taiwan. The conference agenda can be found at http://www.gise.ntnu.edu.tw/sml2003/. Several of the papers published in this issue of IJSME were presented at the conference.

Among those attending the conference, a concensus emerged, that the seemingly radical views once espoused by early advocates of the constructivist perspective have become mainstream thinking in many countries. In many ways, the constructivist framework represents the first generally accepted paradigm of the science and mathematics education research communities. In its simplest form, the major assertions of constructivism, now taken as Lakatosian "hardcore assumptions," are: (1) that human beings are meaning-makers; (2) that the principal goal of science, mathematics and education therein is the construction of shared meanings, and (3) that shared meanings may be facilitated by the active intervention of well-

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prepared teachers (Mintzes, Wandersee & Novak, 1998, 2000; Wandersee, Mintzes & Novak, 1994).

Within this broad framework, hundreds of studies have focused on a wide range of issues related to conceptual development, cognition and learning. The results of these studies may be summarized as a series of knowledge claims which have received widespread though not necessarily unanimous support in the research literature. These conclusions are not new but their implications are so broad and potentially important that they deserve repeating in this international forum.

CLAIM 1. Learners subscribe to a host of alternative scientific and mathematical views which contrast with those offered by scientists, teachers, and textbooks.

CLAIM 2. Many of these alternative views are found in males and females of all ages, abilities, social classes and cultures; other views may be unique and culture-bound. These views typically serve a useful function in the everyday lives of individuals.

CLAIM 3. Alternative views are often "tenacious and resistant to extinction" by conventional teaching strategies (Ausubel et al., 1978).

CLAIM 4. Alternative views interact with knowledge presented in formal instruction resulting in unintended consequences that may remain hidden from teachers and students themselves.

CLAIM 5. Views that students bring to formal instruction often resemble those of previous generations of scientists, mathematicians and natural philosophers.

CLAIM 6. Alternative views have many sources, including direct observation, peer culture, everyday language, the mass media, and formal classroom intervention.

CLAIM 7. Deep or radical conceptual change is not something that can be achieved easily through one or two sessions of instruction, feedback, or analogical illustrations (Chi, 1992). When conceptual change is difficult, it is often because student's lack awareness of their misunderstanding, or they lack an alternative category to shift concepts into (Chi & Roscoe, 2002).

CLAIM 8. Classroom teachers often subscribe to the same alternative views as their students.

CLAIM 9. Successful learners develop strongly hierarchical, coherent, frameworks of interrelated concepts, and they represent those concepts at a deeper, more principled level than less successful learners.

CLAIM 10. Understanding and conceptual change are products of conscious attempts by learners to make meanings; they are accomplished by restructuring an existing knowledge framework through an orderly set of cognitive processes.

CLAIM 11. Students' conceptions allow both scientific and personal meanings of science and mathematics to coexist and access to both meanings is context-dependent.

CLAIM 12. Differences in the abilities of individuals to solve problems are attributable primarily to the structure of their knowledge in domain-specific areas.

CLAIM 13. Successful science and mathematics learners habitually employ a set of metacognitive strategies which enable them to plan, monitor, control and regulate their own learning.

CLAIM 14. Recent advances in instructional intervention suggest that conceptual change can be accomplished by well-prepared teachers in conventional classroom environments.

Building on this general constructivist framework and its principal knowledge claims, the authors in this issue of *IJSME* (Volume 2, No. 2) offer a series of important contributions:

- John Gilbert describes the value of models and modeling as a route toward enhancing the authenticity of the science curriculum.
- Peter Hewson takes us beyond the role of individual learner characteristics and into the realm of tools, tasks and the learning environment as major determinants of conceptual learning in science.
- Chiung-Fen Yen et al., Jing-Ru Wang and Sheau-Wen Lin further our knowledge of alternative conceptions in the biological sciences, focusing on animal biodiversity, internal transport and plant growth and development.
- Fou-Lai Lin et al. contribute a valuable study on algebraic and geometric proof and disproof, focusing on issues of reasoning and understanding in mathematical discourse.

- Ron Tzur and Martin Simon offer a theoretical discussion of two stages, participatory and anticipatory, in the acquisition of new mathematical conceptions.
- Jya-Yi Wu Yu and colleagues describe how junior high school students understand the validity of conditional statements in mathematical reasoning and argumentation.

In our view, these papers represent some of the relevant thinking about learning currently available in the science and mathematics education communities. We recommend them heartily, especially to young researchers who seek models of excellence in research.

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